National Aeronautics and Space Administration

Eliminating Doubt in the Climate Observation and Modeling System

SUMMARY

CLARREO

Observing, tracking, and modeling Earth's climate system are by far some of the most complex undertakings human have ever attempted. Newsworthy examples like weather-related natural disasters, flooding from intense rainfall, and changes in crop growing patterns from temperature fluctuations are becoming more frequent, raising questions about how climate change is already affecting people around the world, both physically and financially. Our understanding is that over time, climate change is likely to increase the frequency of such extreme heat and rainfall events. Policy makers, governments and businesses need to make informed decisions in response to climate change based on accurate, tested, and trusted climate measurements.

What's missing from the current Earth Observation System? We need high accuracy direct observations over a long enough time to detect climate change trends and to test and systematically improve predictions. **CLARREO can meet this need.**

The CLARREO mission will be the first space-based laboratory to measure the Earth while continually verifying the measurements against International Standards. This verification process will improve the accuracy of the whole climate measurement system by allowing for intercalibration of many of the existing climate measurements. CLARREO will produce a benchmark of the Earth's climate, providing a standard that can be confidently compared with measurements of climate change 5, 10, 20, even 50 years after the mission's launch.

CLARREO provides the cornerstone of future climate observations and is a mission that:

1. Has significant value to the world economy

- CLARREO's economic value to the world economy by accelerating the ability to make informed policy decisions about climate change has been estimated using the U.S. Interagency Memo of the Social Cost of Carbon (2010) at ~$20 Trillion for a 2.5% discount rate, $12 Trillion for a 3% discount rate, or $3 Trillion for a 5% discount rate.
- CLARREO also provides major benefits in the near term. Observations of the far infrared spectrum will help answer outstanding questions about the upper atmosphere. Plus, the high accuracy observations will provide the basis to better assess systematic errors in weather forecasting models.

2. Will help optimize climate change mitigation and response policies through benchmarks

- CLARREO provides new benchmarks for high accuracy and high confidence observations of decadal climate change across a wide range of critical climate variables from temperature to humidity to clouds to energy balance to land cover.
- CLARREO climate change benchmarks will be critical 5, 10, 20, even 50 years after the mission's launch as society works to optimize climate change mitigation and response policies.
- CLARREO climate change benchmarks of Earth's full infrared and reflected solar spectra will provide some of the most critical tests of the accuracy of climate change predicted by climate models. These tests are essential to understanding the uncertainty in predicting future climate change.

3. Bridges observing system gaps and allows for international intercalibration

- Understanding climate change requires consistent observations over many years. Long records can be broken by gaps between satellite missions. CLARREO's unprecedented accuracy provides the first space observations that can bridge observing system gaps while maintaining high confidence climate change data needed for policy decisions.
- CLARREO's mission orbits, pointing, and sampling capabilities are designed to provide the first climate change reference intercalibration to other key weather, research, and climate satellite instruments that observe infrared or reflected solar wavelengths. Examples include:
  - IASI and CrIS infrared sounder weather observations,
  - VIIRS, AVHRR & MODIS global imagers for cloud, surface, and vegetation properties,
  - CERES and GERB for the climate system energy balance

4. Is led by the world's experts in long term climate and chemistry measurements from space

- CLARREO engages expertise from around the nation and the world to ensure that the leading climate modelers and observation scientists from different universities and agencies come together and collaborate. For example, NASA's Langley Research Center leads the mission, the science and the IR instrument. NASA's Goddard Space Flight Center leads the RS instrument. NIST helps to ensure expertise in calibration.
- CLARREO is led by the Science Directorate at NASA's Langley Research Center, a group known internationally for its 34-year history in very high accuracy long-term climate and chemistry measurements.
  - 23 instruments launched since 1978, which is about one every 18 months
  - New instruments are preparing to launch -- SAGE III/ISS will launch in 2016
  - 100% rate of successful delivery and operation on orbit
  - 98% success rate on instrument science delivery for 23 instruments
  - Average instrument lifetime on orbit is 9 years
  - Langley space instruments have led to approximately 3,500 journal papers and 100,000 journal citations.
  - The data products have 160,000 unique data users

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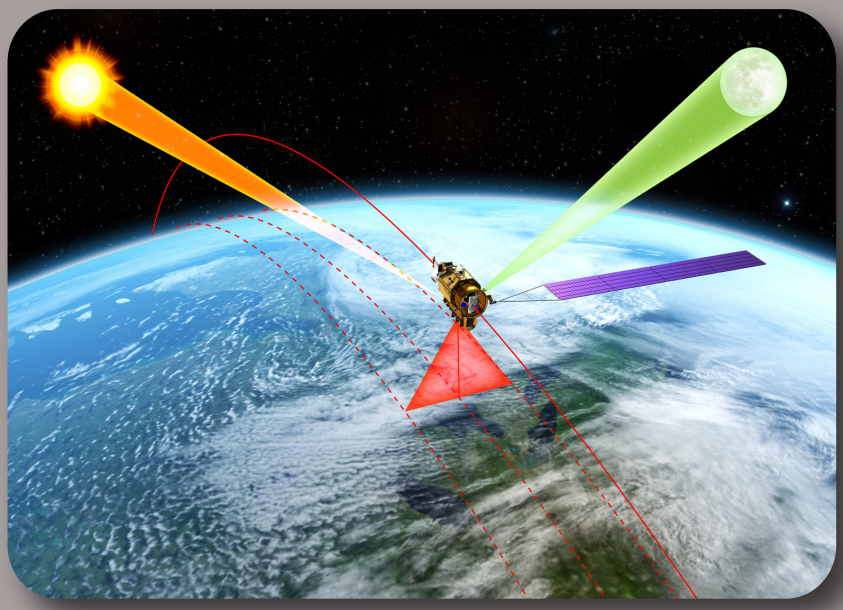

CLARREO accuracy does for climate observations what GPS did for navigation

Image left: CLARREO uses the moon as a reference for stability in orbit, the sun to verify instrument nonlinearity of gain across the Earth viewing dynamic range, and it has the ability to directly scan deep space to verify instrument offsets.

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